12 JUL 24 1956

Volume 42 JULY, 1956 Number 7

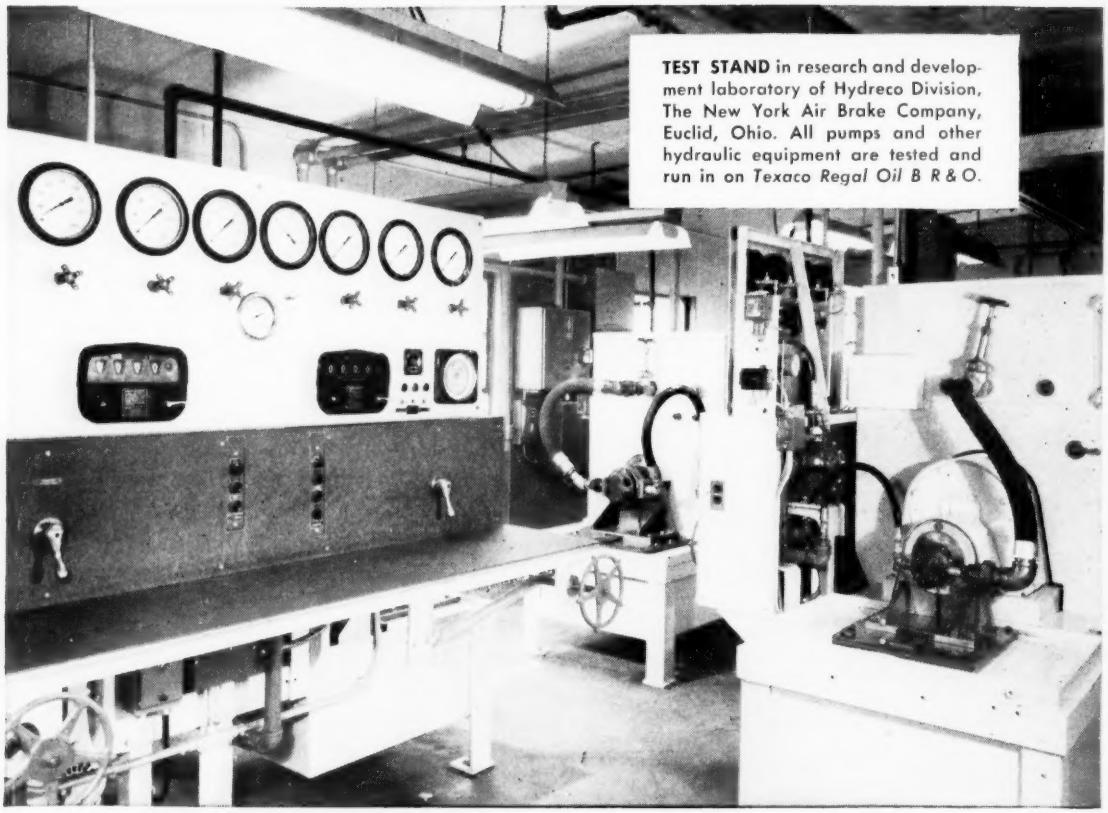
Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

This Issue

INDUSTRIAL HYDRAULIC OILS

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS



TEST STAND in research and development laboratory of Hydreco Division, The New York Air Brake Company, Euclid, Ohio. All pumps and other hydraulic equipment are tested and run in on *Texaco Regal Oil B R & O.*

On-the-job comparison proves Texaco best . . .

BACK IN 1948, Hydreco Division, The New York Air Brake Company, started using *Texaco Regal Oil R&O* for testing and calibrating hydraulic valves and pumps—and for five years enjoyed smooth, trouble-free performance with no rust, no sludge, no foam.

Then, about two years ago, Hydreco decided to try a "less expensive" competitive hydraulic oil. Efficiency dropped off, downtime and maintenance costs went up. Within six months, Hydreco was back on *Texaco Regal Oil R&O.* As new tests stands are added, *Texaco Regal Oil R&O* goes into use without question.

Similar outstanding performance of *Texaco Regal Oil R&O* has proved to operators everywhere that premium quality is invariably the least expensive. Tests show that *Texaco Regal Oil R&O* has *more than ten times the oxidation resistance* of ordinary hydraulic oils—superior ability to prevent sludge, rust and foam. It keeps systems clean for dependable performance, extends the life of pumps and other parts.

Let a Texaco Lubrication Engineer help you get these benefits in your plant. Just call the nearest of the more than 2,000 Texaco Distributing Plants in the 48 States, or write:

The Texas Company, 135 East 42nd Street, New York 17, N. Y.

TEXACO REG T.M.

TEXACO Regal Oils R & O

FOR ALL HYDRAULIC UNITS

LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

Published by
The Texas Company, 135 East 42nd Street, New York 17, N. Y.
Copyright 1956 by The Texas Company
Copyright under International Copyright Convention. All Rights Reserved under Pan-American Copyright Convention.

J. S. Leach, Chairman of the Board of Directors; A. C. Long, President; R. F. Baker, J. W. Foley, Executive Vice Presidents; M. Halpern, Senior Vice President; C. B. Barrett, S. C. Bartlett, T. E. Buchanan, S. T. Crossland, F. M. Dawson, H. T. Dodge, Oscar John Dorwin, E. R. Filley, Robert Fisher, F. H. Holmes, A. N. Lilley, J. H. Pipkin, J. T. Wood, Jr., J. S. Worden, Vice Presidents; W. G. Elicker, Secretary; E. C. Breeding, Comptroller.

Vol. XLII July, 1956 No. 7

Change of Address: In reporting change of address kindly give both old and new addresses.
"The contents of 'LUBRICATION' are copyrighted and cannot be reprinted by other publications without written approval and then only provided the article is quoted exactly and credit given to THE TEXAS COMPANY."

Industrial Hydraulic Oils

SUCH features as flexibility, versatility, compactness, basic simplicity, and economics have all combined to make "hydraulics" an increasingly popular means of transmitting power. Hydraulic systems can give a larger mechanical advantage or force multiplication, with less bulk, than electrical or mechanical systems designed to do the same job. The fact that hydraulic force can be shunted easily through small high pressure tubes by a fluid, pushed by a pump located in some convenient place, has made hydraulic systems a "natural" for countless applications. The following discussion concerns the requirements of a fluid for use in industrial hydraulic systems.

This is the first in a series of two articles relating to the broad field of industrial hydraulics. It is concerned mainly with the fluid – its requirements, properties, and characteristics, and the factors that should govern its selection. The second article, to appear in the August issue, will discuss ways and means of keeping the oils and the systems clean.

Experience has shown that hydraulic systems, if treated with a reasonable amount of care, will seldom cause trouble. However, when trouble does occur, the expense can be excessive due to high repair costs and lost production time. The question that naturally arises is, what constitutes reasonable care? What steps can be taken to assure satisfactory performance and trouble-free operation of a hydraulic system?

The first step involves the selection of the proper fluid. Generally, too little attention is given to this item. In most instances, an oil that meets certain physical or chemical specifications is considered satisfactory by the user, and little or no consideration is given to any of the other properties that might bear on its performance. Secondly, it is most essential that the hydraulic oil be installed in clean equipment. Finally, both the oil and the system should be maintained in a clean condition. Hydraulic mechanisms are precision units, and it is hardly necessary to point out the ill effect that sludge, dirt or contamination of any kind will have on the close fitting parts of the pumps, valves or cylinders.

A hydraulic system may be perfect with respect to design and construction, but if the fluid employed therein is either initially unsuitable or is in improper condition, not only will the operation of the equipment be unsatisfactory, but also damage to the unit may result. The selection of the proper fluid and careful maintenance to assure that it is kept in good condition are just as important to the smooth, efficient operation of a hydraulic system as the choice of the equipment itself. This has been most emphatically demonstrated by the results of a survey made for the purpose of classifying the various causes of

operating difficulties in industrial hydraulic systems. This survey revealed that of the troubles encountered:

10% are due to improper diagnosis of trouble or lack of "know how" in making repairs.

10% are due to mechanical failures such as bearing failures from misalignment, seal failures due to dirt, etc.

5% are due to operation of units beyond recommended limits of speed, pressure or volume.

5% are due to miscellaneous unclassified causes, ranging from excessive packing friction on hydraulic rams to chatter resulting from inadequate lubrication of ways.

70% are due to improper condition of the hydraulic oil.

From this survey it will be noted seventy per cent of the reasons for service complaints can be attributed to the improper condition of the hydraulic oil. What more forceful statistics could be found to emphasize the importance of choosing with care the proper type and grade of hydraulic oil?

WHAT IS REQUIRED OF THE HYDRAULIC FLUID?

The primary function of the hydraulic fluid is to transmit a force applied at one point in the system to some other location and also to reproduce quickly any change in direction or magnitude in this force. In order to accomplish this, the fluid must be relatively incompressible and must flow readily.

In addition to the main duties, there are certain other functions which are required of the fluid and although they may be secondary in nature, they are extremely important to the successful operation of the system. Some of these functions are:

1. The fluid must provide an adequate seal between the moving parts so as to reduce both internal and external friction.

2. During its useful life, the fluid should undergo little physical or chemical change.

3. It should not in itself promote rusting and corrosion of the component parts of the system.

4. It must possess adequate film strength at all times in order to minimize wear of the moving parts of the equipment.

5. The fluid should permit rapid settling and separation of insoluble contaminants that enter the system.

6. It should be available in quantity.

Petroleum oils are ideally suited for the vast majority of industrial hydraulic applications. They can be used over wide temperature ranges, are available in quantity, are relatively cheap, possess good lubricating characteristics, and will not in themselves promote rusting or corrosion.

SELECTION OF A HYDRAULIC OIL

The choice of the most satisfactory hydraulic oil for a given application should be based on two entirely separate and distinct considerations, neither one of which bears upon the other, namely, (1) the initial suitability of the oil and (2) the quality of the oil.

Each individual system requires that the oil used therein must have certain physical properties and characteristics in order to perform satisfactorily. These properties have no relationship to the quality of the oil, but if they are not observed, the system will not function properly regardless of how good the oil may be. On the other hand, the quality reflects the performance characteristics of the oil and how well it resists those factors inherent in hydraulic systems which tend to shorten its service life. Although specifications based on certain physical properties will permit the selection of oils that will be expected to fulfill the initial basic requirements for a particular application, they will not foretell the length of time that these oils will be expected to perform satisfactorily in service. Herein lies the difference among hydraulic oils, and it is in this regard that the user must exercise his judgment and discretion in accordance with his needs.

INITIAL SUITABILITY

The selection of an oil meeting the basic suitability requirements for use in an industrial hydraulic system is not complicated and involves consideration only of viscosity, viscosity index and, in some cases, pour point of the oil. Frequently, users of hydraulic oils will require the oil to meet certain specifications that have no relationship to, or correlation with, the hydraulic application of the oil. Such properties as gravity, color, flash point, carbon residue and neutralization number have little or no significance in determining the initial suitability of a new oil. However, some of these tests are valuable as guides in checking on the condition of used oil to determine its suitability for continued service.

Viscosity and Viscosity Index

Viscosity is the most important single property of an oil from the standpoint of its use in industrial hydraulic systems. Viscosity refers to the "body" which a fluid possesses and may be regarded as a measure of its resistance to flow or of its internal friction. More specifically, it is a measure of the resistance in moving one layer of liquid over another. It is actually defined as the force per unit area required to move a layer of fluid at a rate of one centimeter per second past another parallel layer one centimeter away. It is denoted by a quantity u, called the coefficient of viscosity, and is expressed mathematically as

$$u = \frac{F/A}{V/L}, \text{ or Poise} = \frac{\text{Shear Stress}}{\text{Rate of Shear}}$$

For practical purposes, relative viscosities can be used and these are determined by timing the flow of a given quantity of oil through a standard orifice at a constant temperature. There are numerous accepted methods for determining relative viscosities of oils, but the one most commonly employed for industrial hydraulic oils is the Saybolt Universal method. The test is usually conducted at 100°F. and the results are expressed as the number of seconds required for 60 ml. of oil to pass through a standard orifice.

Factors that prevent hydraulic systems from operating at 100% efficiency include pump slippage, cavitation, fluid friction, oil leakage, mechanical friction and rate of response. The viscosity of the oil will affect all of these efficiency determining factors.

If the viscosity of the oil is too high, some of the undesirable results that will occur are:

1. The internal friction of the fluid will increase, which in turn will increase the flow resistance through the clearances of the pumps and valves.
2. The temperature will increase.
3. The operation will become sluggish.
4. Pressure drop throughout the system will increase.
5. Power consumption will increase.

The following are some of the undesirable results that will occur if the viscosity of the oil is too low:

1. Internal and external leakage will increase.
2. Pump slippage will increase, which will reduce pump efficiency and increase oil temperature.
3. Rate of wear of moving parts will increase.
4. System will lose pressure.
5. There will be a loss of precision control.

The over-all viscosity requirements of oils for industrial systems depend on such factors as design features, size, operating pressures and temperatures. For each hydraulic system, there is a certain viscosity or limited viscosity range which will give most efficient and most satisfactory performance. It would be ideal if the fluid would maintain its viscosity at a constant value at all conditions. However, all fluids thin out at high temperatures and thicken up at low temperatures. Also, the viscosity will increase as the pressure increases. Thus, it is obvious that the ultimate selection from a viscosity standpoint must be the best possible compromise, since this property varies both with temperature and pressure. It is generally accepted that the viscosity of an oil in service should never exceed 4000 SSU and never be lower than 45 SSU.

The pump is usually the most critical part of the system with respect to viscosity, and pump manufacturers make very specific recommendations as to the proper viscosity that should be employed. These recommendations should be very carefully observed.

The rate of change in viscosity with a change in temperature is measured by a quantity called the *viscosity index*. This is a quantity that is calculated from actual viscosity determinations made at 100°F. and 210°F. The higher the viscosity index value, the less will be the change in viscosity with temperature. Paraffinic oils as a group have much higher viscosity indices than do naphthenic oils. By solvent refining an oil from a paraffin base crude, viscosity indices in the range of 80-110 can be obtained. This range represents about the highest that can be realized economically by a combination of proper crude oil selection and solvent refining.

The Viscosity Index of an oil can also be increased by the use of certain additives, termed Viscosity Index or "VI" Improvers. Such materials are usually polymers or long chain hydrocarbons. Additives of this type have been used in oils in hydraulic equipment, such as in aircraft, exposed to much wider temperature ranges than usually encountered in industry. Undoubtedly they will find some additional use in other unusual hydraulic applications subjected to wide temperature variations. Disadvantages encountered with some of the earlier VI Improvers were their tendency to break down at high rates of shear, and also their high cost.

It is readily agreed that there are advantages to be obtained in using hydraulic oils having high viscosity indices. Any increase over that obtainable with well refined mineral oils, however, must be evaluated in terms of the ultimate cost to the consumer versus operating results obtained. With the exception of aircraft and certain relatively limited industrial applications where price may be of secondary consideration, evidence indicates the additional cost of incorporating viscosity index improvers in industrial hydraulic oils is not justified in terms of service performance.

The viscosity index of an oil becomes important if the oil in a given application will be subjected to a wide temperature range. In such cases, it is imperative that a high VI oil be used. If not, the oil may be so thick when the equipment is started that it won't flow properly, or it may be so thin at the highest operating temperature as to produce all of the unfavorable results of a low viscosity oil previously discussed. If the equipment will not be subjected to low temperatures and if the oil temperatures will always be confined to rather narrow limits, then the viscosity index is not important.

Consider the chart shown in Figure 1, which is a plot of viscosity vs. temperature for two oils, each

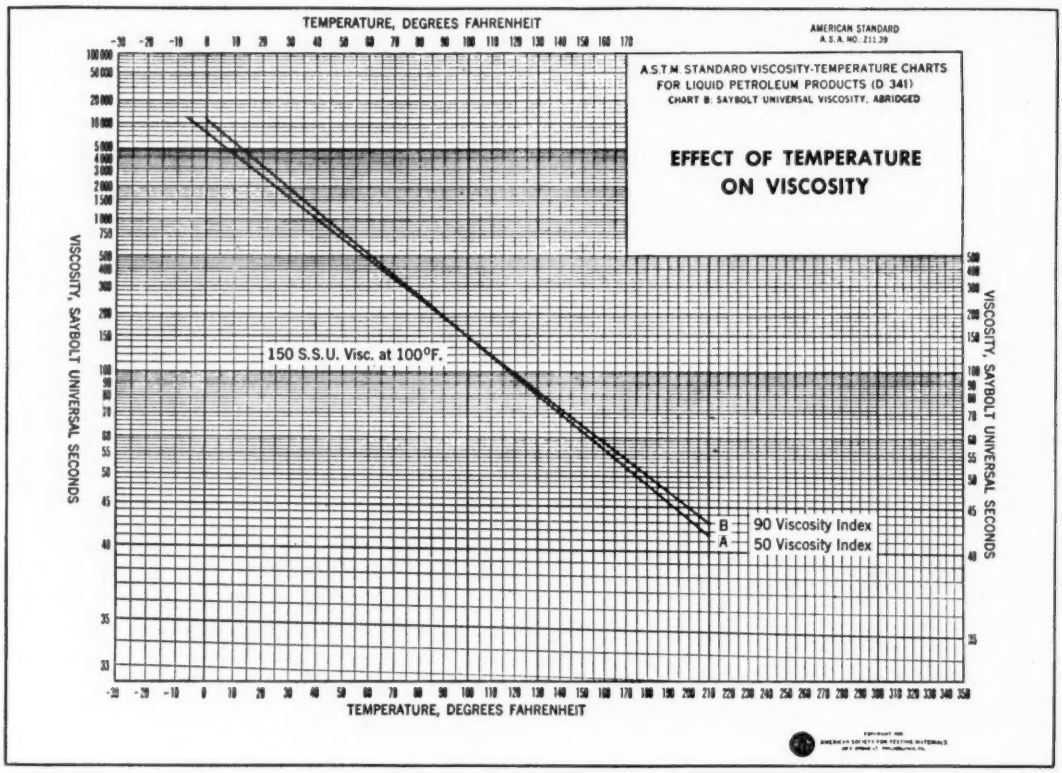


Figure 1 — Temperature vs. viscosity of two oils having the same viscosity at 100°F. but different viscosity indices.

having a viscosity of 150 seconds at 100°F. but one having a viscosity index of 50 and the other 90. This chart is so designed that the viscosity at any temperature can be determined by plotting the viscosities at two temperatures and drawing a line through the points. Oil A, with a viscosity index of 50, has a viscosity of 4000 seconds at 17°F; Oil B with a viscosity index of 90 has this same viscosity at 12°F. Thus, assuming that the viscosity of an oil in service should not exceed 4000 seconds, it is apparent that increasing the viscosity index of an oil from 50 to 90 permits a reduction of only 5°F. in the minimum operating temperatures.

Pressure has the following general effects on the viscosity of petroleum oils.

1. A unit increase in pressure will have a greater effect at high pressures than at low pressures.
2. The viscosity of naphthene oils is affected more than is that of paraffinic oils.
3. Oils of lower viscosity are affected less than oils of higher viscosity.
4. An increase in pressure will increase the viscosity index of an oil.

Figure 2 illustrates the effect of both temperature and pressure on the viscosity of an oil having an initial viscosity of 167 seconds at 100°F. and atmospheric pressure. If this oil were used in a hydraulic system operating at 9900 psi pressure and if the oil temperatures on the high pressure side of the system varied from 100°F. to 140°F., then it it apparent from the chart that the viscosity of the oil in this part of the system would range from 750 seconds to 280 seconds.

Pour Point

The pour point is the lowest temperature at which the oil will flow when chilled under given conditions and is of concern only if the hydraulic system is to be exposed to low temperatures. A good rule to follow is that the pour point should be about 20°F. below the lowest temperature to which the oil will be exposed.

QUALITY OF HYDRAULIC OILS

Although the properties just discussed are those required for the oil to accomplish its primary function in a hydraulic system, they tell nothing about the quality of the oil — how it will perform its secondary functions so important to the over-all operation of the system—how long it will continue to perform both its primary and secondary functions — how well it will resist changes in its essential properties. It is in these respects that hydraulic oils vary widely. Properties that reflect the quality of the oil include oxidation stability, rust prevention,

foam resistance, water separation and film strength, among others.

In the early years of hydraulic power, straight mineral oils, particularly those that were highly refined, were entirely suitable. Hydraulic circuits were simple and valves were hand-operated so that there was plenty of power available to pry them loose should they stick. High wear and high maintenance costs were accepted as a matter of course.

However, production demands are now much greater. Systems are more complicated, and operating conditions have become more severe. High maintenance costs are regarded with disfavor. Production lines usually include many individual hydraulic machines, thus making it imperative for all machines to be operating full time. All of these factors point to the need for better and better hydraulic oils.

Today's premium grade hydraulic oils start with the selection of a suitable crude oil. Even with the best selected crude, only part of the hydrocarbons in the appropriate viscosity range have the desired chemical structure. Improved refining methods have increased the selectivity and efficiency of removing unsuitable compounds. Today, there is an imposing and flexible array of refining procedures that can be employed:

Vacuum Distillation to obtain the proper fraction or viscosity range
Solvent Refining to improve the viscosity index, oxidation stability, color and inhibitor response
Solvent Dewaxing to lower the pour point
Deasphalting to remove asphalt-like materials
Acid Treating to remove sludge forming bodies and improve oxidation stability and color
Clay Contacting and Clay Percolation to remove acid bodies and improve demulsibility and color

However, this is just the beginning as far as the manufacture of premium hydraulic oils is concerned. Additives are incorporated to supplement and improve certain of the properties such as oxidation stability, rust protection and foam resistance. This involves a lot more than simply the addition of some chemicals to an oil. Skill is required in both the selection and use of additives. An inferior oil cannot be converted into a premium product simply by the inclusion of an additive. Some oils respond well to chemical additives, while others do not. A given oil may respond to one type of additive, but not to another. Some additives may improve one property of the oil and at the same time, degrade other properties. Consequently, the manufacture

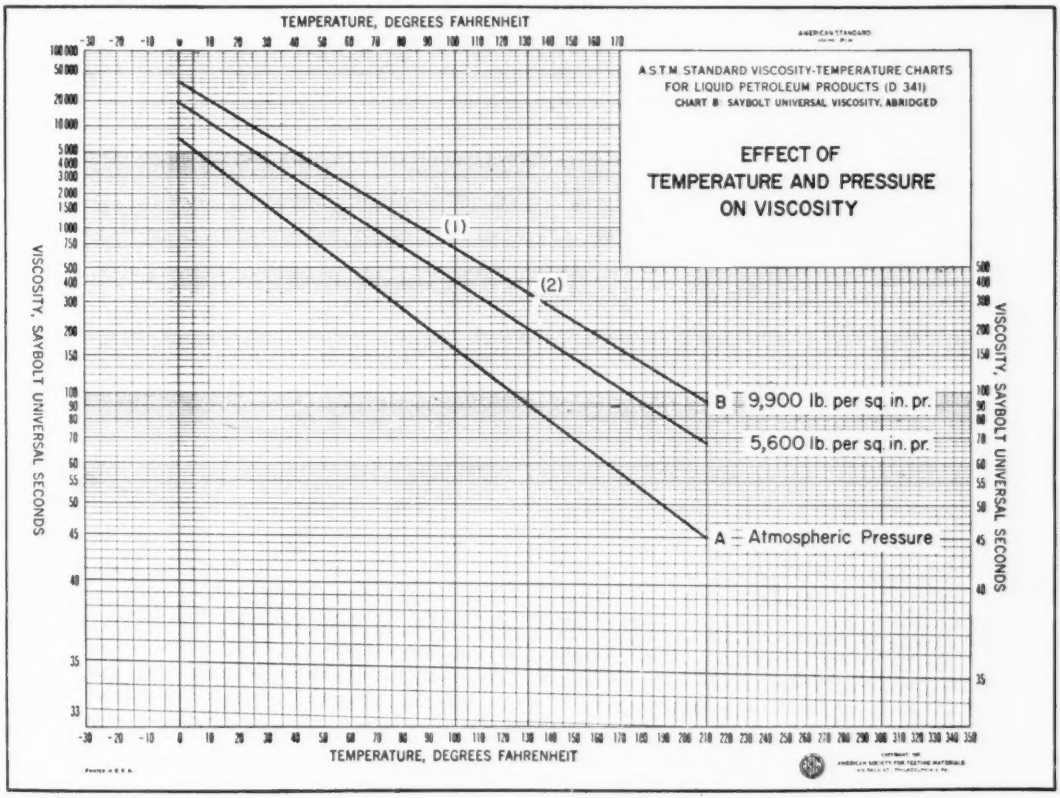


Figure 2 — Temperature and pressure vs. viscosity.

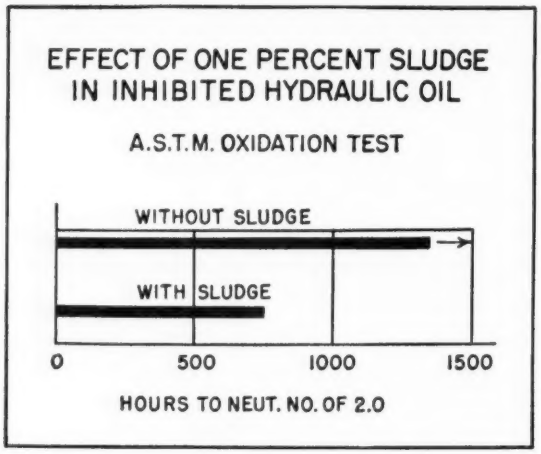


Figure 3 — How a small amount of sludge can increase the oxidation of an oil.

of a premium grade hydraulic oil involves consideration of a number of factors that are not immediately apparent.

Oxidation Stability

Perhaps the most important property of an oil from a quality standpoint is its chemical or oxidation stability. This property may be regarded as the life line of the fluid, since oxidation is the greatest factor that shortens the life of the oil.

All hydrocarbons are susceptible to oxidation, which can be regarded as the reaction of oxygen with the oil to form a multitude of compounds. The reaction will occur stepwise, and the first products formed are usually the unstable hydroperoxides. These in turn will react to form such compounds as alcohols, aldehydes, ketones, acids, and oxy-acids, all of which may be soluble in the oil. Subsequently, through polymerization and condensation reactions, insoluble gum, sludge and varnish will be formed. The soluble acidic products increase the viscosity of the oil and can be corrosive to the metals in the system. On the other hand, the insoluble products will cause the operation to become sluggish, will increase wear and will eventually reduce clearances, plug lines and valves and cause the system to become inoperative.

As might be expected, oils vary widely in their oxidation stability, depending on their type, the method of refining and whether or not oxidation inhibitors are present. In a hydraulic system, the rate of oxidation is not only a function of the oil, but also of the operating conditions. Temperature, pressure, contaminants, water, metal surfaces and agitation all favor oxidation and all are present in a hydraulic system.

Temperature is a primary accelerator of oil oxidation. It is well known that the rate of any chemical reaction, including oxidation of hydrocarbons, will approximately double for every 18°F. increase in temperature. Below 135°F., the oxidation rate is quite slow, but above this value it becomes a rather critical factor. In fact, it is estimated that the life of an oil will be decreased 50% for every 15°F. temperature rise above 140°F. The temperature of the oil in the reservoir is not a true indication of the actual oil temperatures involved. The oil temperature on the discharge side of the pump is a better guide. Even then, there may be hotter surfaces where local oxidation can occur.

As the pressure increases, the viscosity of the oil likewise will increase. This in turn will develop more frictional heat which will raise the operating temperature of the oil and accelerate oxidation. Also, the amount of air that can be held in solution by oil increases sharply with an increase in pressure. At atmospheric pressure and room temperature, oils contain about 10% by volume of dissolved air. At 200 psi pressure, approximately 140% by volume can be absorbed. Any dissolved air will provide oxygen necessary to promote oxidation.

Contaminants such as cutting oils, greases, dirt, moisture, paint, joint compounds and insoluble oxidation products themselves all accelerate the rate of oil oxidation. Figure 3 shows the effect of one per cent sludge on the oxidation stability of an inhibited oil, as determined by the ASTM Oxidation test.

Metals, particularly copper, are known catalysts for oil oxidation and their catalytic effect is greatly enhanced by the presence of water. Figure 4 shows the effect of iron and copper, both with and without the presence of water, on the oxidation stability of an uninhibited mineral oil. The presence of each metal greatly increases oil oxidation, and the presence of water accelerates it drastically. Although not shown on the chart, the catalytic effect of

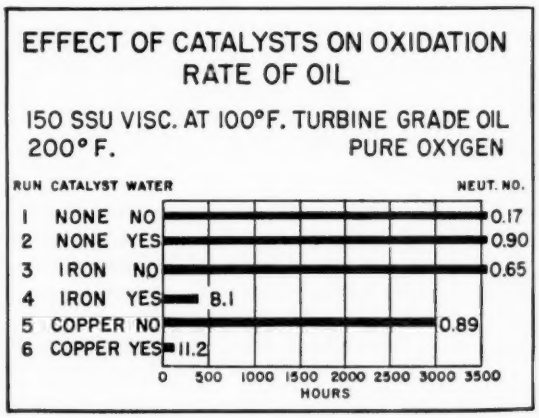

EFFECT OF CATALYSTS ON OXIDATION RATE OF OIL
150 SSU VISC. AT 100°F. TURBINE GRADE OIL
200° F.
PURE OXYGEN
RUN CATALYST WATER
NEUT. NO.
1 NONE NO 0.17
2 NONE YES 0.90
3 IRON NO 0.65
4 IRON YES 8.1
5 COPPER NO 0.89
6 COPPER YES 11.2
0 500 1000 1500 2000 2500 3000 3500
HOURS

Figure 4 — How the presence of metals and water can increase the oxidation of an oil.

TABLE I

Effect of Inhibitors in Various Base Oils
Vis. of Base Oils: 300 Sec. Sav. Univ. @ 100°F.

	Hrs. Required for 2.0 Neutralization Number in ASTM Oxidation Test	
Type Base Oil	Without Additives	With Additives
Red Engine Oil	Approx. 75	169
Pale Machine Oil	Approx. 75	405
Turbine Grade Oil	Approx. 75	1625

aluminum is very similar to that of iron.

Thus, it should be readily apparent that normal conditions in a hydraulic system are very favorable for promoting oil oxidation which will greatly reduce the service life of the oil. Premium quality hydraulic oils contain inhibitors which nullify or decrease the influence of the factors that promote oil oxidation. Oxidation inhibitors will usually function in one of two general ways: (1) they may be of the chain breaker type that interrupts the oxidation reaction soon after it starts and prevents the reaction from continuing, or (2) they may be of the metal deactivator type which reduces the catalytic effect of the metals. In any event, the preparation of a high grade hydraulic oil involves careful consideration of the choice of both a proper highly refined base stock and the additives. It is easier to make a silk purse out of a sow's ear than it is to make a premium grade hydraulic oil by the indiscriminate blending of chemicals in an oil. Table I clearly indicates the extent to which the quality of the base oil can affect the ultimate oxidation stability of an inhibited oil.

Since oxidation stability is the most important quality property of an industrial hydraulic oil, it is not surprising that many laboratory tests have been devised to evaluate this characteristic. During recent years, an increasing number of users have included some sort of a beaker-type oxidation test in their purchase specifications for hydraulic oils. Some of the tests are static, while others are dynamic; some employ aeration and others do not; some use catalysts and some don't. Also, various end points are employed to compare the oxidation stability of the oils tested. These include the length of time to reach a specified neutralization number increase or a given quantity of sludge; neutralization number increase or the amount of sludge deposited in a given time; pressure drop, or simply visual observation.

The fallacy of relying heavily upon such tests is that by adjusting the test conditions employed, a series of oils can be made to rate in any order desired.

Frequently the tests used were designed originally to evaluate internal combustion engine oils where higher temperatures are encountered, and these tests do not apply at all to hydraulic oils. In any kind of a laboratory bench test designed to rate oils in accordance with their service performance, acceleration of some sort is necessary. However, to be meaningful, only those factors that change during actual service should be accelerated and accelerated only in their proper proportion. The use of abnormally high temperatures to accelerate oxidation can be particularly misleading in comparing premium grade hydraulic oils. Some additives employed to inhibit oxidation may be adversely affected by these high temperatures and consequently oils containing them may be ruled out by one of these bench tests, whereas in actual service they may be superior to oils that do pass the test.

It is also unwise to use static tests to compare the oxidation properties of oils. Frequently in a static test, the comparison of two oils can be completely reversed simply by changing the length of time for which the test is run.

The inadequacy of accelerated bench tests to rate the oxidation stability of hydraulic oils is demonstrated rather vividly by the data presented in Table II. This shows the relative rating of five industrial hydraulic oils when evaluated in eight different bench tests. The five oils are premium

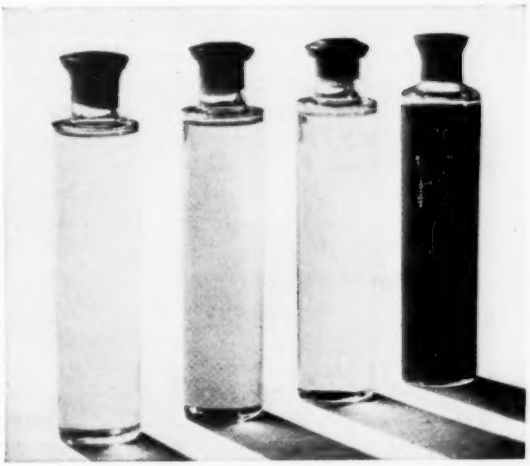


Figure 5—New and oxidized oils from the ASTM oxidation test.
Left — New inhibited hydraulic oil.
Left Center — Same oil after 1000 hours. Neutralization Number is 0.1.
Right center—New turbine grade mineral oil.
Right — Same oil after 1000 hours. Neutralization Number above 2.0.

TABLE II

Evaluation of the Oxidation Stability of Industrial Hydraulic Oils By Accelerated Bench Tests

Test	A	B	C	D	E	F	G	H
Test Conditions								
Temperature, °F.	300	400	220	225	250	239	260	205
Time, hours	125	96	330	100	168	—	—	—
Aeration	No	Moist air	Dry air	No	No	No	Oxygen	Oxygen
Catalyst	No	No	Copper	Copper, iron	No	Copper	Copper, steel	Copper, iron, water
Relative Ratings of Oils								
Oil No. 1	1	1	2+	1+	2	1	2	4
Oil No. 2	4+	3	1	3	1	3	1	3
Oil No. 3	2	4	4	1+	3	4	3	1
Oil No. 4	3	5	2+	4	4	2	4	5
Oil No. 5	4+	2	5	5	5	5	5	2

grade products from five different suppliers, and all have impressive service performance records. The eight laboratory tests are representative of those actually employed by purchasers to qualify hydraulic oils. The oils were assigned ratings of from 1 to 5 to indicate their relative performance in each test. A rating of 1 represents the best, while one of 5 is the worst. The lack of correlation among the various tests is clearly evident from the data presented. Only two of the eight tests (E and G) rate the oils in the same order. Any one oil may rate anywhere from near the top to close to the bottom of the list depending upon the test used. For example, in test B, Oil No. 1 ranks first and Oil No. 3 is fourth. However, in test H their relative ratings are exactly reversed. In tests B and H, Oil No. 4 ranks fifth and Oil No. 5 is second. In tests C and F these ratings are reversed.

The foregoing merely confirms what has already been stated: that by the judicious selection of catalyst and test conditions, a series of oils can be made to rate in different orders. More serious is the fact that such oxidation tests may have little or no relation to actual performance. Simulated performance tests, conducted under conditions approximating those to which the oil will be subjected in service, provide a much safer and more realistic basis for evaluating the oxidation and other quality characteristics of industrial hydraulic oils. Such tests, however, are too elaborate and time-consuming to be employed by most of the users of hydraulic oils. Consequently, in selecting a product, the purchaser should make his selection on the basis of the service background and history of the oil rather than on the results of some simple laboratory bench test.

Rust Prevention

Undoubtedly, more equipment made of ferrous metals is destroyed by rust than by any other single factor. Hydraulic systems are by no means exempt.

Rust occurs in a hydraulic system because moisture is present due to condensation from air entering through leaks on the intake side of pumps, breathing of air through vents in reservoirs, and contamination. Such rust may not look serious, but it is, particularly if one considers that only one or two flakes of rust passing through precision made pumps and valves can so scratch surfaces that the efficiency of these parts is reduced. Pumps operating at extremely high pressures should be carefully protected against rust, for a scratch on pistons, for example, may permit an excessive amount of slippage — just as an automobile engine loses compression with scored cylinders.

The petroleum chemist has provided a means of preventing rust formation by incorporating suitable inhibitors which keep moisture away from the surface. This is a far more practical means for rust control than complete elimination of all moisture from the system, an expensive and unreliable procedure.

While many theories have been advanced to explain the action of rust inhibitors, the most plausible is that the inhibitor, which has been added to the hydraulic oil, "plates out" on the metal surfaces, forming an adherent film which is impervious to the rusting action of moisture and air.

Actually, the amount of rust inhibitor in the oil is only a fraction of one per cent, yet such a small amount has been proven to be sufficient to protect all metal surfaces in a hydraulic system against rust formation. No attempt has been made to measure the thickness of the protective layer formed, but it cannot be more than several molecules in thickness.

The generally accepted method for testing the effectiveness of such inhibitors in the laboratory is the ASTM Rusting Test. Carefully prepared steel rods are suspended in a mixture of the oil under test and ten per cent water which is agitated rapidly for 24 hours at a temperature of 140°F. In order for the oil to be considered satisfactory, the specimen must show no rusting at the end of the test.

The effectiveness of one rust inhibitor, as shown by results obtained on this very severe test, is illustrated in Figure 6. When using an uninhibited straight mineral oil the rod rusted badly, but when a rust inhibitor was incorporated in the oil, the rod did not rust.

Field experience in thousands of hydraulic systems has proven that the results illustrated in Figure 6 are just as outstanding in actual service. This has been particularly true in humid atmospheres where hydraulic systems in the past have been prone to rust. In such cases, rusting problems have been entirely eliminated by the use of a rust inhibited hydraulic oil.

This protective film, however, can be removed by any mineral oil which is not rust inhibited,

Figure 7 — Rusting and corrosion of a part due to the presence of water contamination in a straight mineral oil.

since, apparently, an equilibrium is set up between the amount of inhibitor plated out and that in the oil. For this reason, if a straight mineral oil is used for makeup after an initial charge of rust inhibited oil, the effectiveness of the rust inhibitor will gradually be lost, for the "plated out" inhibitor will go back into the makeup oil.

Protection against rust is important even in systems where leakage is a factor to contend with. In such systems, it has generally been taken for granted in the past that general machine oils could be used because the oil was replaced at such a rate that it did not have a chance to oxidize materially. Under such conditions, even though oxidation inhibitors may not be particularly valuable, it is still economical to use inhibited hydraulic oils because such systems are prone to permit ingress of moisture, and the presence of the rust inhibitor in the

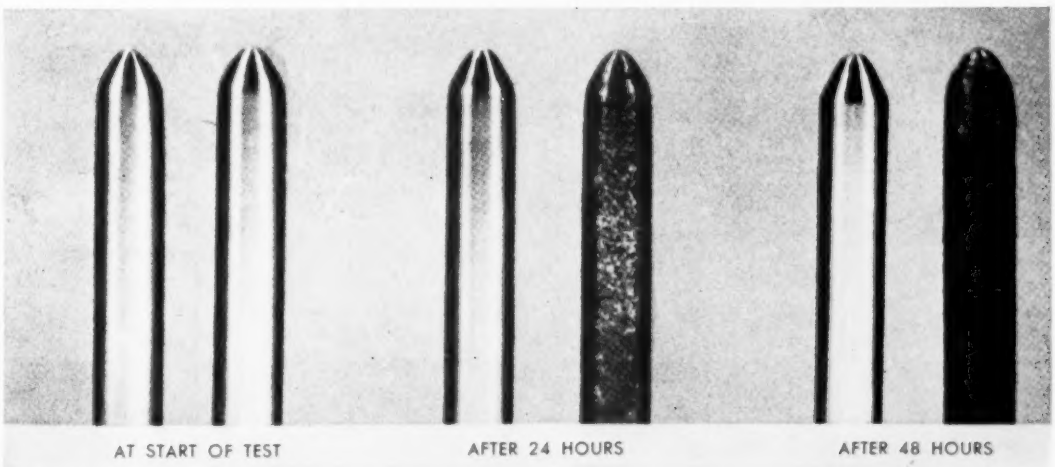


Figure 6 — Steel rods from the ASTM rusting test, the rods on the left represent the result obtained with an inhibited oil, whereas those on the right were obtained with a straight mineral oil.

oil will prevent the possibility of rusting.

Foam Depressants

The presence of troublesome amounts of air in hydraulic systems is due entirely to mechanical causes, such as air leakage into the oil suction line, low level in the oil reservoir permitting the pump suction inlet to become exposed, and leakage around packing. It is important that the cause of air ingress be found and corrected, for it not only may result in erratic movement of machine parts, but may cause the hydraulic oil to oxidize more rapidly.

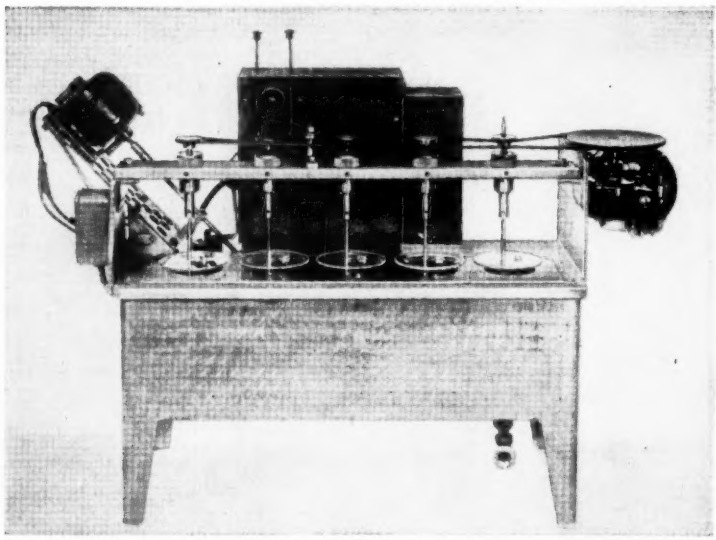
Practically all commercial oils contain some air in solution, roughly 10% by volume, and under pressure they will absorb a great deal more. As long as air is in solution no harm will result, but if air is dissolved in oil under pressure and the pressure is subsequently released, air will come out of solution to produce foam. Separated air, if trapped in a cylinder, is highly compressible whereas oil is not, and for this reason irregular action of cylinders will result.

Air trapped in cylinders has another deleterious effect, for as it is compressed it becomes very hot. For example, if air is quickly compressed to 100 pounds per square inch, the theoretical temperature of the air would be 485°F. and at 3,000 pounds per square inch it would be 2,020°F. In a hydraulic system, if air bubbles or free air were compressed from atmospheric pressure to the above pressures, the resultant temperatures would be somewhat lower, depending upon the rate of compression, absorption into the oil, and heat lost because of conduction. Obviously, though, the temperature would be sufficiently high to scorch the surrounding oil, with the result that oxidation of the oil would take place. Even though heat thus generated may not be sufficient to be noticed in the overall temperature of the oil, continued oxidation of this type is cumulative and will eventually cause the entire batch of oil to become oxidized.

All straight mineral oils are more or less susceptible to foaming, depending upon their viscosity, crude source, type of refinement and usage. Fortunately, foaming can now be reduced to a negligible quantity by the addition of chemical compounds. Such compounds when added to oils do not necessarily keep air from dissolving in oil or foam from forming, but they do cause the foam to break quickly and any entrained air in the oil to separate out rapidly.

The effect of these depressants on the foaming ability of an oil is illustrated in Figure 9. These results were obtained in the laboratory on the Coordinating Research Council Foam Test. The oil on the right is a straight mineral oil of turbine grade. The oil on the left is the same oil to which has been added a foam depressant. In this test, air is bubbled through the oil under standard conditions for five minutes and Plate A Figure 9 illustrates the results obtained at this point. Note how much more foam is produced with the uninhibited oil, also that the bubbles of air in the foam are much finer. The picture represented by Plate B, Figure 9 was taken after the air had been shut off for three minutes, and at this point the foam over the inhibited oil was practically gone. After ten minutes standing (see Place C, Figure 9) there still was a quantity of foam remaining over the uninhibited oil. In fact, it took about 40 minutes for this foam to break out.

From these results, it would be expected that if



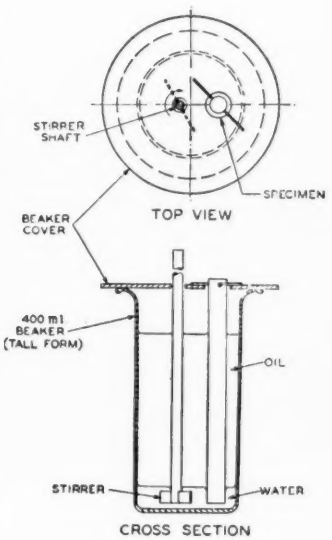


Figure 8 — ASTM rusting test bath and set-up.

TABLE III

Anti-wear Properties of Hydraulic Oils

Simulated Hydraulic Systems
Vane Type Pumps—1000 psi Pressure

Temp. of Operation	175°F.		225°F.	
Oil	Straight Mineral	Premium Grade	Straight Mineral	Premium Grade
Vis. of oil at 100°F. SSU	145	145	305	305
Vis. of oil at operating temperature, SSU	51	51	48	48
Duration of run-hrs.	900	900	650	1140
Cam, net loss-grams	7	0.5	15	1.8
Avg. vane wt. loss-grams	0.07	0.02	0.14	0.01

foam developed in a hydraulic system with oils containing foam depressants, the air would separate out quickly with the result the foam layer on the reservoir would be of negligible thickness. Field experience has certainly borne this out.

Water Separation

Any moisture that enters the hydraulic system, whether through contamination or condensation, may emulsify under the violent churning conditions that exist. The presence of any soluble oxidation products in the oil will increase its tendency to emulsify. The emulsions formed may be thin and slurry, thick and pasty, or heavy and gummy.

Emulsions will promote the collection of dust, grit and dirt, will adversely affect the proper functioning of the valves, and will increase friction, wear and oxidation. These harmful effects will be greatly minimized if the oil will promote rapid separation of the water. Highly refined mineral oils will permit water to separate quickly. There are no additives which can be included in an oil to increase its water separating properties, and in fact care must be taken lest the additives incorporated in the oil for other purposes will actually have an adverse affect on the demulsibility of the oil.

Anti-Wear Properties of Hydraulic Oils

In addition to all of its other functions, the hydraulic oil must lubricate the moving parts of the system so as to reduce wear to an absolute minimum. Wear will result in increased clearances which will then lead to all sorts of operating difficulties, including increased leakage and loss of efficiency. Premium grade hydraulic oils will generally have much better anti-wear properties than will the best straight mineral oils of comparable viscosities.

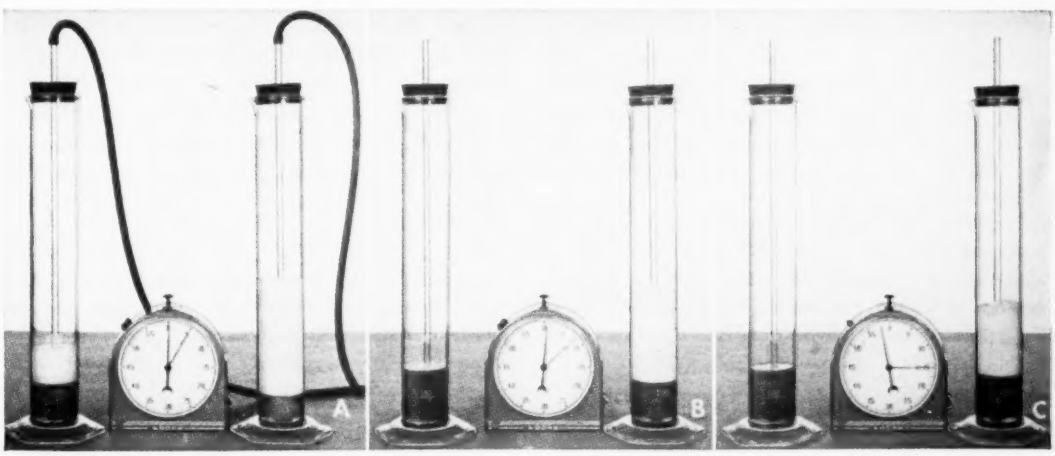


Figure 9 — Foam test results. Straight mineral oil on right and inhibited oil on left.

TABLE IV

Comparative Operation of a Straight Mineral Oil and a Premium Grade Oil

Equipment	Turbine Grade Straight Mineral Oil		Premium Oil	
	Drain Period	Condition	Drain Period	Condition
1. Ten Milling Machines	Frequent	Varnish	Tripled Life	Clean
2. Machine Tool	500-700 Hrs.	Sludge	2400 Hrs.	Clean
3. Riveter	30 Days	Varnish	60 Days	Clean
4. Broaching Machine	14 Days	Rust and Deposits	90 Days	Clean
5. Grinder	3 Months	Clean	2 Years	Clean

This is emphatically demonstrated in Table III, which presents data obtained from tests conducted in a simulated hydraulic system operating with vane type pumps at 1000 psi. Runs were made at both 175°F. and 225°F., and in each instance the wear as determined by cam and vane weight loss was much less with the premium grade oil than with the straight mineral oil.

ECONOMIC FACTORS

Too often the purchase price is the controlling factor in the selection of a hydraulic fluid and little or no recognition is made of maintenance costs. In almost every instance, the increase in initial cost of oils due to the use of premium grade hydraulic oils may be saved many times over by reduced maintenance costs.

For example, one very large midwestern manufacturer was using a fairly well refined straight mineral hydraulic oil in five milling machines. Complaints were made concerning short oil life, sticking of parts and excessive down time. The oil in use was replaced with a premium oil which cost two and one-half times as much. Due to increased oil life, reduced down time, and lack of sludge, gum or rust in the system, however, it was estimated $2,000 a month was saved on these five machines alone.

In another case, involving some eighty grinders, a change in the type of hydraulic oil from a turbine grade straight mineral oil to a premium grade inhibited hydraulic oil resulted in a reduction of 74% in the consumption of hydraulic oil based on storehouse records. This reduction was attributed to greatly extended drain periods with the inhibited type oil.

In making an economic study of the *total* or *final* cost of hydraulic oils, not only the initial price, but many other factors as well must be considered. A listing of factors to be considered must include:

1. Non productive loss on machine during shutdowns to change hydraulic oil or clean out system.
2. Labor involved in changing oil in cleaning out system.
3. Life of oil in system.
4. Cost of flushing oils or cleaning solvents if used to clean systems.

With a premium grade hydraulic oil, maximum life is obtained resulting in minimum down time to change the hydraulic oil and most important, the system is normally clean, meaning that cleaning costs are eliminated. As proof of this, consider the data in Table IV. Changing from a turbine grade straight mineral oil to premium oil resulted in increased service life, ranging up to eight times, and in each case, a clean system when the oil was changed. These data were collected during World War II when machines were operating at overrated capacity and differences in oils showed up in a hurry.

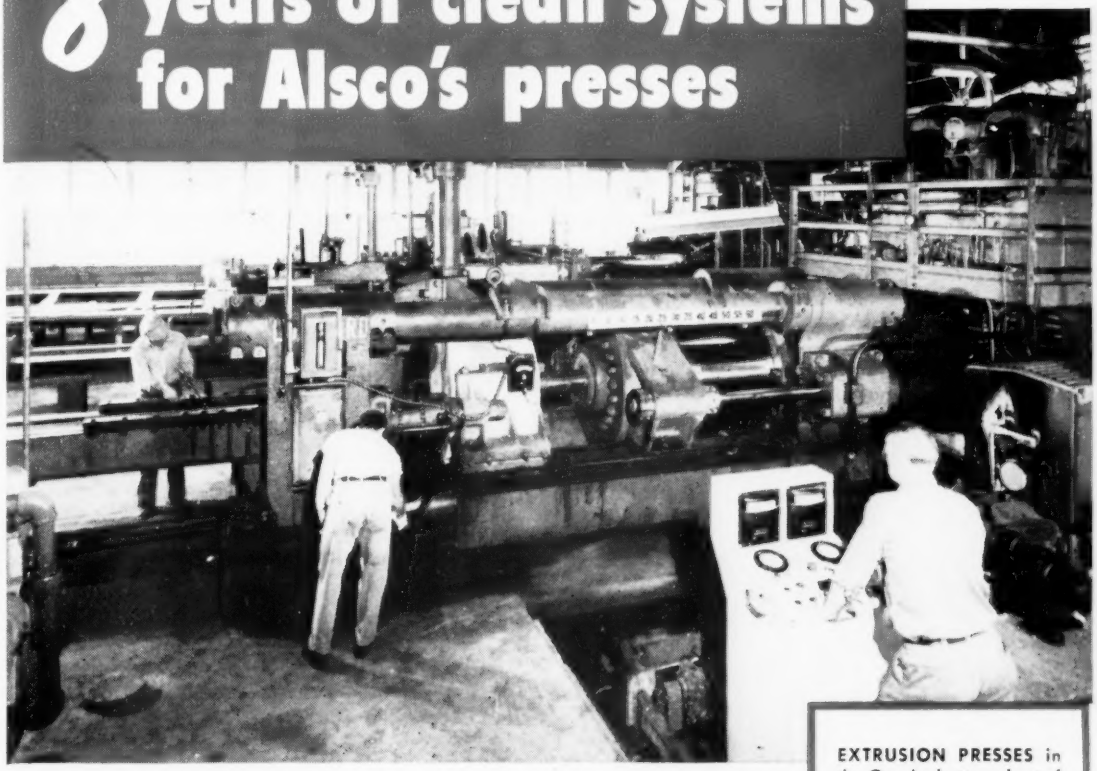
SUMMARY

The choice of the most satisfactory hydraulic oil for an industrial application should be based on two entirely separate and distinct considerations, neither of which bears upon the other, namely, (1) the initial suitability of the oil and (2) the quality of the oil. The former is related to viscosity and sometimes to viscosity index and pour point. The quality is related to such properties as oxidation stability, rust protection, water separation, foam resistance and wear prevention.

Furthermore, in making an economic evaluation of hydraulic oils, many factors in addition to the initial cost of the oil should be considered.

Printed in U. S. A. by
Salley & Collins Inc.
305 East 45th Street
New York 17, N. Y.

8 years of clean systems for Alsco's presses



EXTRUSION PRESSES in the Gnadenhutten plant of Alsco, Inc., Akron, Ohio. Pressures range from 1,100 to 2,000 tons. Operating temperatures are normally 140°F.—may go as high as 160°F. In addition, there are ten smaller pumps actuating the stretchers. All this equipment has used *Texaco Regal Oil R&O* for eight years with outstanding results.

ALSCO, INC., Akron, Ohio, has used *Texaco Regal Oil R&O* as its sole hydraulic fluid for the past eight years. During this period, the hydraulic systems in four heavy duty extrusion presses have remained completely free of rust, sludge and foam.

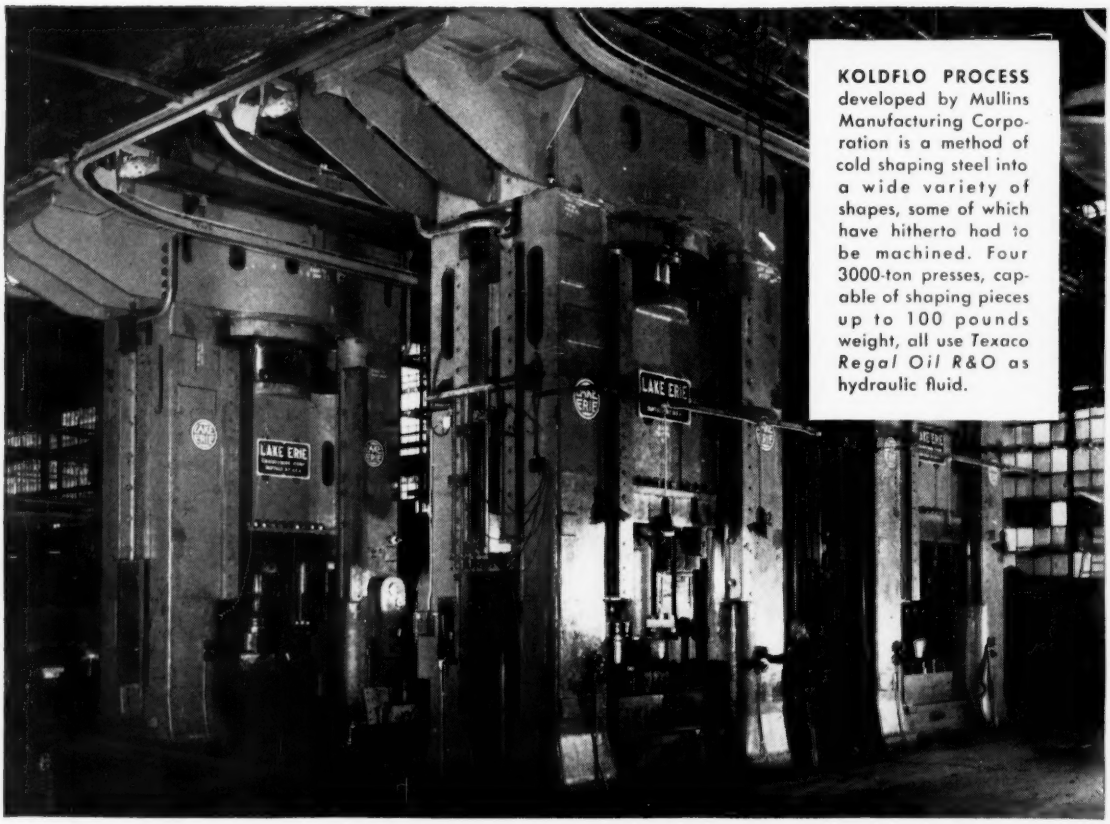
Alsco's experience with *Texaco Regal Oil R&O* reflects the merit of this superior oil. Tests prove that *Texaco Regal Oil R&O* has *more than ten times the oxidation resistance* of ordinary turbine-quality oils. This means proven ability to prevent rust, sludge and foam. The result is extended life for pumps and other vital parts, lower maintenance costs.

There is a complete line of *Texaco Regal Oils R&O* to meet the requirements of every type and size hydraulic mechanism, under every operating condition. A Texaco Lubrication Engineer will help you select the one exactly suited to your equipment. Just call the nearest of the more than 2,000 Texaco Distributing Plants in the 48 States, or write The Texas Company, 135 East 42nd Street, New York 17, N. Y.

TEXACO

TEXACO Regal Oils R&O

FOR ALL HYDRAULIC UNITS



KOLDFLO PROCESS developed by Mullins Manufacturing Corporation is a method of cold shaping steel into a wide variety of shapes, some of which have hitherto had to be machined. Four 3000-ton presses, capable of shaping pieces up to 100 pounds weight, all use *Texaco Regal Oil R&O* as hydraulic fluid.

"Systems completely free of sludge, rust and foam"

—reports Mullins Manufacturing Corporation, Warren, Ohio

FOUR 3000-ton Lake Erie presses went into service in 1953 with an initial fill of *Texaco Regal Oil R&O*—2700 gallons in each system. Two years later, Mullins told us—

> **"Your Texaco Regal Oil R&O has done a great job in assuring the dependable hydraulic performance we must have. All systems are completely free of sludge, rust and foam. Very little make-up has been required."**

Texaco Regal Oil R&O has been proved by test to have *ten times the oxidation resistance* of ordinary turbine-quality oils—far greater ability to keep systems free from sludge, rust and foam. And there is a complete line of *Texaco Regal Oils R&O* to meet the requirements of all types and sizes of hydraulic equipment, all operating conditions.

Let a Texaco Lubrication Engineer help you select the proper one to keep *your* hydraulics trouble-free. Just call the nearest of the more than 2,000 Texaco Distributing Plants in the 48 States or write:

The Texas Company, 135 East 42nd Street, New York 17, N.Y.

THE TEXAS COMPANY • • • DIVISION OFFICES

ATLANTA, GA......864 W. Peachtree St., N.W.
BOSTON 16, MASS......20 Providence Street
BUFFALO 5, N. Y......P.O. Box 368
BUTTE, MONT......220 North Alaska Street
CHICAGO 4, ILL......332 So. Michigan Avenue
DALLAS 2, TEX......311 South Akard Street
DENVER 3, COLO......1570 Grant Street
HOUSTON 2, TEX......720 San Jacinto Street
INDIANAPOLIS 1, IND., 3521 E. Michigan Street
LOS ANGELES 15, CAL.....929 South Broadway
MINNEAPOLIS 3, MINN.....1730 Clifton Place
NEW ORLEANS 16, LA......1501 Canal Street
NEW YORK 17, N. Y......205 East 42nd Street
NORFOLK 2, VA......3300 E. Princess Anne Rd.
SEATTLE 1, WASH......1511 Third Avenue

TEXACO

Texaco Petroleum Products are manufactured and distributed in Canada by McColl-Frontenac Oil Company Limited.